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ADDRESS OF THE RETIRING PRESIDENT OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC IN AWARDING THE BRUCE MEDAL TO M. HENRI POINCARÉ.

BY FREMONT MORSE.

It is the custom for the retiring president of this Society, in the years when the Bruce Medal has been awarded, to give in his annual address a statement of the reasons for the award; and so this evening it is my duty and pleasure to present for your consideration certain facts in the life of M. HENRI POINCARÉ, the distinguished French mathematician who is the recipient of the medal this year.

Let me first state something of the history of the medal and of the conditions under which, and the recommendations by which the Board of Directors of the Society make their decision as to whom the medal shall be given.

As is well known to most of you, the endowment which furnishes the income to pay for the Society's medal was donated by Miss CATHARINE BRUCE, of New York, and amounts to $2,500, the interest of which sum suffices to provide the medal approximately annually. In the cases where the accrued interest is not sufficient the awarding of the medal is omitted for a year, as was the case last year.

Now, as you are aware, this is a Society made up, and governed, largely by amateurs, and the question may naturally arise: "Wherein, to a distinguished professional astronomer, lies the value of any medal that may be awarded by such an association?" The reply, full and convincing, lies in the rules governing the award. By these rules the nominations of persons eligible to receive the honor is vested in the directors of six of the leading observatories of the world,—viz.: The Lick, Yerkes, and Harvard, in this country; Greenwich, in England; Paris, in France, and Berlin, in Germany.

The statutes provide that early in September our Secretary shall communicate with the director of each of these observatories, and request him to nominate some candidates for the honor, grouping them in the order of his preference. The nominations thus received are communicated to the directors of the Society previous to the November meeting, and at that meeting a choice is made by ballot from among the names presented. The directors are pledged to secrecy as to the names put forward, but I think I shall not be overstepping the bounds if I tell you something of the method by which they arrive at their conclusion. It is the custom to tabulate the nominations received each year on a sheet that contains all the nominations of previous years, so that at a glance it may be seen not only what names have been presented in the current year, but how many times each has been put forward in previous years and by what observatories. In the final choice all the nominations, of past years as well as the present, may be taken into account.

Thus it is clearly evident that any astronomer, however distinguished, may well be gratified at the receipt of an honor thus bestowed. And it is equally plain that the medal can never go to anyone not eminently worthy of the distinction.

Our medalist of this year was born in Nancy in the province of Lorraine, France, April 29, 1854, of a distinguished family, which had numbered among its members men active and noted in the community as magistrates, scholars, lawyers, and soldiers.[1] His grandfather was a pharmacist, which fact may have influenced his father in the choice of medicine as his profession. It is said of the father that "he was a conscientious student, a distinguished practitioner. He was one of those men who, having been led by a noble curiosity into the most emotional and uncertain of professions, practice it with admirable disinterestedness, and hold themselves amply rewarded if they are so fortunate as to save a human life now and then.

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[1] For the biographical data herein contained I am indebted to the address of M. MASSON, the celebrated French historian, delivered on the occasion of M. POINCARÉ's admission to the French Academy.—*F. M.*

For the honor of the nation there are many such men in France; but few have been able, like Dr. POINCARÉ, to discharge the duties of so absorbing a profession, to work in the laboratory, to teach assiduously, and at the same time to travel extensively over Europe."

His mother was also born of an old family in the same province of Lorraine, and she is described as "one of those alert, active women, always in motion and always busy, whose spirit of order, organization, and command rules a household." Two of her uncles are said to have been skilled in mathematics, and her brother, a graduate of the École Polytechnique, was an inmate of the household during POINCARÉ's boyhood. Thus example and inherited aptitude may both have influenced his choice of profession in later years.

Like many another intellectual genius POINCARÉ's health during early childhood was delicate, and a serious illness suffered when he was five years of age left him still more enfeebled, and it was at one time feared that he would never recover from what, fortunately, proved only a temporary loss of speech. But the illness left him frail, timid, and disinclined for the rough, noisy sports of boyhood.

It may be that the world of science is a gainer from this circumstance, for had POINCARÉ's sturdy brain led a perfectly developed physical frame in the sports of youth and early manhood he might never have developed that genius for abstract reasoning that has made him so famous. He would, in any event, have been a leader in his chosen field, whatever that might have been. Being, however, disinclined for boyish sports on account of the lack of robust health, his attention was early turned to books, and he found great pleasure in popular scientific treatises. His early education was begun under a tutor in his father's house, whose scheme of education did not involve the use of text-books, but consisted principally of talks about things. And the information of the teacher was fortunately such that he was able to impart knowledge in all needful branches of learning by this method.

It is probable that to this sort of early training POINCARÉ owes one peculiarity of his memory—that it is more auditory than visual, or, in other words, that spoken, rather than written words, make the greater and more lasting impression upon it.

From this sort of teaching POINCARÉ went into the Lycee of Nancy, where the superior quality of his mind was soon apparent. He excelled in all his studies, and it is said that his literary ability was so marked that his teacher in that line strove to lead him towards literature as a calling. But his bent was in another direction. He was naturally inclined to mathematics.

His schooling was interrupted at the age of sixteen by the outbreak of the Franco-Prussian war. His youth and his delicate health both prevented him from joining the army and fighting for his country; and being unable to take active part at the front he did the best he could to aid by serving as secretary to his father and helping him daily at the hospital in the care of the sick and wounded.

The result of the war was the passing of Alsace and Lorraine under German rule, and, as a writer says, "it was under the yoke of a victorious enemy and in a city occupied by the Germans that POINCARÉ again took up his studies." On graduation from the school at Nancy he gained highest honors, and carried off the prize in mathematics from rivals from Paris and all the departments, and could have entered the School of Forestry as second on the list of appointees had he so desired. Instead he applied for admission at the École Polytechnique, and in his examinations ranked number one. It is said that "his residence there is a matter of piously transmitted tradition. He is credited with attending his classes in mathematics without taking a note, without reading or even collecting the mimeographed sheets which reproduced the professor's lectures." His method was "to classify the results established, to study their connection, with no care for the demonstrations, sure of finding others if he happened to forget the ones they had employed."

At the closing examinations his superiority in mathematics was so decided that in spite of his inaptitude for the so-called practical studies, he was placed second and admitted to the School of Mines. He became an engineer in 1879 and in the same year a doctor of sciences.

It was in 1880 that the Paris Academy of Sciences set as the subject of the great prize in mathematics the theory of differential equations. When the report on the papers that had been presented was made, one by an anonymous author was specially mentioned, and the author was urged to persevere in a work which promised to produce important results. This paper was by POINCARÉ, but was "only a first sketch and presented only the results which he was soon to obtain and which in the month of February, 1881, burst forth—it is the only exact phrase, says one of his admirers—in the report of the Academy of Sciences. From week to week, with the notes that he sent out regularly, his discovery increased in precision and amplitude for a period of nearly two years. His contribution was the crowning of the work of CAUCHY and RIEMANN, the representation of the co-ordinates of any algebraic curve in uniform functions, the integration of linear differential equations with algebraic coefficients—it was a new and immense perspective opened to view."

In 1881 he was called to Paris, where in 1886 he became Professor of Mathematical Physics and the Calculus of Probabilities in the Faculty of Sciences. In 1896 he took the chair of Celestial Mechanics.

All during his career POINCARÉ has been a prolific writer on all subjects related to mathematics. His investigations cover the entire field of mathematical science, pure and applied. It is said that his published books and memoirs number more than three hundred. These I will not attempt to enumerate, but content myself with the mention of the work most celebrated, the one which deals most intimately with astronomy and forms the principal basis of the award of the Society's medal. I refer to his "Celestial Mechanics." The world's greatest mathematicians have ever been attracted to the problem of the motions of the heavenly bodies. It could hardly have been otherwise, for where could genius find a grander outlet than in the endeavor to solve the problem of the universe? So naturally M. POINCARÉ became an investigator in the realm of celestial mechanics. His great work upon this subject I am competent neither to review nor discuss, and therefore that you may gain some idea of its nature and scope I quote extensively from a review published in the *Monthly Notices* of the Royal Astronomical Society in 1898, just before the publication of the final part of it. The reviewer says:—

"New and important fields of research have been opened up to dynamical astronomers during the past twenty years. The impetus was originally given by Dr. HILL's papers on the lunar theory. Since then, continental mathematicians have applied to the problem of the three bodies the varied resources of modern analysis. M. POINCARÉ, himself one of the most distinguished of living workers in this field, has collected the results of recent research in the three volumes of his 'Methodes Nouvelles de la Mécanique Céleste'—a work of which we are glad to notice the approaching completion.

"The first volume appeared in 1892. After two preliminary chapters—one on the general differential equation of dynamics, and one on integration by infinite series—the author commences in the third chapter the study of periodic solutions. Among the solutions of the general problem of three bodies, there are some in which the relative movement repeats itself at regular intervals of time. A class of these 'periodic solutions,' as they are called, was discovered by Dr. HILL in his 'Researches on the Lunar Theory,' published in the *American Journal of Mathematics*. Much of the theory in its present form is due to M. POINCARÉ himself. It was developed in a memoir on the problem of three bodies, which gained the King of Sweden's prize in 1889, and it is the main theme of the present volume.

"The problem attacked may be stated thus: In the problem of three bodies, let two of the bodies have their masses zero. Then a class of periodic solutions of the system is known,—namely, the motions in which these bodies describe circular orbits about the third body. Is there a corresponding class of solutions when the two masses are small, but no longer zero? Existence theorems are given for such motions, and periodic solutions are arranged in three classes. It is shown that in the second and third of these classes the arbitrary constants of the motion must be such that no secular terms occur.

"Much of the remainder of the volume is occupied with the theory of motions which differ only slightly from periodic solutions. Periodic solutions may at first sight seem to be of no practical interest. It is clearly unlikely that the initial circumstances of the motions will be such as to give rise to an exact periodic motion. But it may well happen that they differ only slightly from such values; the periodic solution can then be treated as a first approximation, or 'intermediary orbit,' just as KEPLER's ellipse is in the older theories, and we can regard the actual motion as a disturbed form of it. Dr. HILL has developed the lunar theory in this way. M. POINCARÉ arrives at a general theory of 'asymptotic solutions' and their 'characteristic exponents.' If the characteristic exponents are purely imaginary, the periodic solution is a stable form of motion. The case of the problem of three bodies is described at some length, and it is shown that the periodic solutions then have two, but not more than two, of their characteristic exponents zero.

"An important chapter is devoted to the integrals of the equations of motion. Herr BRUNS has proved (*Acta Mathematica,* XI) that the problem of three bodies, and more generally of n bodies, admits of no algebraic integral other than those already known. M. POINCARÉ further develops this theorem by proving that for small values of one of the masses there is no uniform transcendental integral.

"The sixth chapter deals with the development of the disturbing functions, particularly in respect to long-period inequalities. In seeking to complete his theorem on the non-existence of uniform integrals the author has discovered an extension of DARBOUX's work on terms of higher orders in expansions.

"The second volume, published in 1893, treats of the methods of GYLDEN, NEWCOMB, LINDSTEDT, and BOHLIN. In the ordinary development of the planetary theory the co-ordinates of the planets are expressed in terms of the time, as infinite series; by taking a sufficient number of terms of the series it is theoretically possible to calculate the place of the planet with any desired accuracy. But these series have one great defect—they contain terms which increase indefinitely with the time. The efforts of mathematicians have lately been successful in obtaining series free from these 'secular terms' as they are called. The developments thus obtained, however, are not convergent in the ordinary sense of the word; having in this respect some analogies with the well-known 'semi-convergent' expansions for Bessel Functions. This, as M. POINCARÉ remarks, does not affect their use for the purposes of calculation, but renders them useless for researches into the stability of the system.

"Although the results obtained in the second volume are largely due to the other workers, M. POINCARÉ has introduced considerable modifications in his account of their theories.

"The third volume, of which the first part has lately appeared" [remember that this was written in 1889], "includes the rest of the work originally given in the memoir 'Sur le Problème des trois Corps,' already mentioned. The theory of integral invariants, which was first developed there, is of importance in questions of stability."

The review concludes by remarking that "this work will be a noble monument of the dynamical astronomers of this generation, and its completion will be awaited with interest."

After its completion it received many other high tributes of praise from mathematicians qualified to judge of its worth.

Thus, in speaking of POINCARÉ, a distinguished American astronomer says: "POINCARÉ's investigations have dealt chiefly with pure mathematics, with mathematical physics, and with mathematical astronomy. Very few living men of science are competent to speak in detail concerning the value of his work, but there can be no doubt that it is of very high rank. His comprehension of the general principles underlying these subjects is remarkable. In giving mathematical expression to these principles POINCARÉ possesses real genius, probably unequalled by that of any other living man.

"POINCARÉ's 'Méthodes nouvelles de la Mécanique Céleste' is probably the most learned existing treatise on the general laws governing the motions of celestial bodies; such, for example, as those of the planets and moons of the solar system. As DARWIN has said of the three volumes composing this work: 'It is probable that for half a century to come it will be the mine from which humbler investigators will excavate their materials. The range is so vast, and the number of new ideas is so great, that I find myself in considerable difficulty as to how to speak of this book.'

"Referring definitely to only one subject of study, POINCARÉ has made remarkably valuable contributions on the subject of the origin of double and multiple stellar systems. With mathematical elegance he has traced the forms which a single rotating homogeneous fluid would assume by virtue of secular loss of heat, and resulting contraction in volume and decrease of rotation period, leading to a fission of the original mass into two masses revolving around their mutual center of mass. POINCARÉ and DARWIN, the two great students of this problem, have supposed that the process described may have been active in the evolution of celestial systems. Their developments of the subject were entirely along theoretical lines. It is interesting to note the evident confirmation of their results afforded by the now abundantly existing observations of spectroscopic and visual binary stellar systems."

Another astronomer, writing in a recent number of *The World's Work,* and reviewing the progress of astronomy during the past decade, says: "Stars may be divided into two classes, single stars, like our Sun, traveling with their retinues of planets, and binary systems, composed of two (or sometimes more) comparable companions. These double stars are among the most beautiful of telescopic objects, as everyone with a small telescope knows. Why do they exist? is the question. Some time since Sir GEORGE DARWIN and POINCARÉ (the well-known French mathematician) showed the mechanical importance of tidal action in the evolution of the heavenly bodies; how a body spinning faster as it contracted upon itself might ultimately split into two parts, and that then the tides raised in each by the other would push the pair farther apart, at the same time rendering their orbits more and more eccentric. Dr. T. J. J. SEE applied this principle to the case of double stars, showing how much more eccentric than the planetary orbits were the orbits of the visual double stars; he suggested that tidal action had accomplished this.

"Now, as a coincidence, comes an interesting observational sequel: the recent corroboration of such a genesis by the stars themselves. CAMPBELL (the present director of the Lick Observatory) first and independently, and more profoundly, SCHLESINGER (of the Allegheny Observatory), BAKER, RUSSELL (of Princeton), and others have shown, from intercomparison of the many spectroscopic binaries (double stars) discovered of late years, that as the size of the orbit increases its eccentricity increases, too. In other words, while double stars are still young in their evolution and consequently near together, their orbits are circular; then, as tidal action gets in its work, just those concomitant effects are produced which theory predicted."

Another expert opinion as to our medalist's ability is found in the closing portion of Sir GEORGE DARWIN's address on the occasion of the presentation of the gold medal of the Royal Astronomical Society to M. POINCARÉ last year. He says: "The leading characteristic of M. POINCARÉ's work appears to me to be the immense wideness of his generalizations, so that the abundance of possible illustrations is sometimes bewildering. This power of grasping abstract principles is the mark of the intellect of the true mathematician; but to one accustomed rather to deal with the concrete the difficulty of completely mastering the argument is sometimes great. To the latter class of mind the easier process is the consideration of some simple concrete case, and the subsequent ascent to the more general aspect of the problem. I fancy M. POINCARÉ's mind must work in another groove than this, and that he finds it easier to consider first the wider issues, from whence to descend to the more special instances. It is rare to possess this faculty in any high degree, and we cannot wonder that the possessor of it should have compiled a noble heritage for the men of science of future generations."

I have already referred to POINCARÉ's literary ability. Less than two years ago he was elected to membership in the French Academy, that most celebrated of all literary societies. It has been intimated that since the special function of the Academy is the preparation of a dictionary, it is probable that the reason for his election was that the Academy might number among its members an eminent authority on the meaning and use of scientific terms. It strikes me that this could hardly have been the true motive; it certainly is not a noble one. My own opinion is that he was eminently qualified by his literary attainments for membership. Literary ability does not consist merely in skill in the fashioning of an ode, or the writing of a page of history, or of fiction. The concise, accurate statement of a scientific truth, the ability to clearly and intelligibly set forth new and abstract principles in the domain of science, is equally literary; and judged by this standard POINCARÉ was clearly entitled to literary as well as scientific honors. No one can read his "Science and Hypothesis" and his "Value of Science" without being impressed with his power of accurate statement and wealth of illustration.

Let me close by quoting a few paragraphs from the latter volume. He says in one place: "So when a rule is established we should first seek the cause where this rule has the greatest chance of failing. Thence, among other reasons, come the interest of astronomical facts and the interest of the geologic past: by going very far away in space or very far away in time, we may find our usual-rules entirely overturned, and these grand overturnings aid us the better to see or the better to understand the little changes which may happen nearer to us, in the little corner of the world where we are called to live and to act. We shall better know this corner for having traveled in distant countries with which we have nothing to do."

In another place he states the reasons why a scientist is impelled to his labors in the following terms: "The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful. If nature were not beautiful, it would not be worth knowing, and if nature were not worth knowing, life would not be worth living. Of course I do not here speak of that beauty which strikes the senses, the beauty of qualities and appearances; not that I undervalue such beauty, far from it, but it has nothing to do with science: I mean that profounder beauty which comes from the harmonious order of the parts, and which an intelligence can grasp. This it is which gives body, a structure, so to speak, to the iridescent appearances which flatter our senses, and without this support the beauty of these fugitive dreams would be only imperfect, because it would be vague and always fleeting. On the contrary, intellectual beauty is sufficient unto itself, and it is for its sake, more perhaps than for the future good of humanity, that the scientist devotes himself to long and difficult labors.

"It is, therefore, the quest of this especial beauty, the sense of the harmony of the cosmos, which makes us choose the facts most fitting to contribute to this harmony, just as the artist chooses from among the features of his model those which perfect the picture and give it character and life. And we need not fear that this instinctive and unavowed prepossession will turn the scientist aside from the search for the true. One may dream a harmonious world, but how far the real world would leave it behind! The greatest artists that ever lived, the

Greeks, made their heavens; but how shabby it is beside the true heavens, ours!

"And it is because simplicity, because grandeur, is beautiful that we preferably seek simple facts, sublime facts, that we delight now to follow the majestic course of the stars, now to examine with the microscope that prodigious littleness which is also a grandeur, now to seek in geologic time the traces of a past which attracts because it is so far away."

I have thus endeavored to give you a brief biographical sketch of our medalist's life; to show, from the writings of scientists competent to judge of his attainments, the nature of his work, and from his own writings to give some extracts to show his literary ability. And now, to sum up, it may be said that M. POINCARÉ's studies and researches cover the entire field of mathematics, pure and applied. In mathematical astronomy he is to-day the leading investigator. His work on the "New Methods of Celestial Mechanics" covers the whole field. In it he has collected the results obtained by all the world's noted mathematicians, dove-tailed them together, so to speak, and added the results of his own studies, which have, all around the ever-expanding circle of human mathematical knowledge, pushed the boundaries farther and farther out into the previously unkown; and it is for this that we, tonight, honor our Society in honoring him.

Living as we do on the outskirts of Western civilization, it has unfortunately always occurred that our medalist has been unable to be present. This occasion is no exception to the rule, and we are also unfortunate, as you have already been informed in the report of the committee having the procurement of the medal in charge, in the fact that the medal has not yet been received from the French mint. But it is on the way, and, Mr. Secretary, I request that when you transmit it to Professor POINCARÉ you will assure him of our high appreciation of his attainments, and of his distinguished services to astronomy, and that you will express to him our hope that he may enjoy many more years in his chosen field of research.